1.2 Antibiotics dispensing in children, 9 years and under

Why is this important?

Much of current antibiotic use is inappropriate, with antibiotics being prescribed for viral illnesses when their use is not indicated.[1] More than 30 million prescriptions for antimicrobials were dispensed to people of all ages in the Australian community in 2015, with no change in this number since 2008.[2] There are harms associated with high use of antibiotics. For example, development of bacterial resistance that means some antibiotics are no longer effective in combating infections. Antimicrobial resistance is known to be increasing in Australia.[2] Other potential harms of high use of antibiotics are now being investigated. Antibiotic use in children is associated with a higher risk of asthma, Crohn's disease and weight gain, although researchers are still exploring these links.[3-6]

What did we find?

The rate of dispensing of antibiotics to children aged 9 years and under is almost equivalent to one antibiotic prescription annually per child in this age group in Australia.

What can be done?

Improving antibiotic prescribing has been a focus of attention for many years, but there has been limited success in reducing rates.[7-10] Sustained and concerted efforts to ensure patient and community awareness of the potential harms associated with antibiotic use in children are essential.[2,11] Improving patient knowledge of the trade-offs between likely benefits and harms has been shown to reduce the use of antibiotics.[12,13] Tools to assist with shared decision making should be promoted to ensure that parents are properly informed about appropriate use of antibiotics in their children. More attention needs to be given to strategies that would encourage clinician adherence to guidelines on appropriate prescribing.[11]

Antibiotics dispensing in children, 9 years and under

Context

This item focuses on rates of antibiotic dispensing for children aged 9 years and under. Antibiotics are used to treat infections, and to prevent infections in some susceptible patients (for example, during some types of surgery).[14] Antibiotic use in Australia is highest in children aged 0–9 years and in older people (aged 65 years and over).[2]

Upper respiratory tract infections are a common reason for seeking medical care, accounting for 26% of paediatric general practitioner (GP) consultations in Australia.[15] As most respiratory tract infections are caused by viruses, antibiotics have a limited role in treatment and should be reserved for cases in which a bacterial cause is suspected.[7] Inappropriate use of antibiotics was highlighted by a 2017 Australian study showing that GPs prescribed antibiotics for acute respiratory infections in children and adults at 4–9 times the rate expected if guidelines were followed.[1] Australia's rate of antibiotic use for children aged 9 years and under is about three times higher than that of similar countries such as Norway and the Netherlands.[8]

Antibiotic use promotes bacterial resistance, both in the individual and the community.[9,16] For example, an individual prescribed an antibiotic for a respiratory tract infection is more likely to carry bacteria resistant to that antibiotic within 12 months of use.[17] Longer duration of antibiotic use and multiple courses are associated with higher rates of bacterial resistance in an individual.[17] Children appear to be important transmitters and recipients of resistant bacteria[18], so inappropriate antibiotic use in children affects rates of resistance in the whole community.

Evidence of a link between childhood antibiotic use and an increased risk of chronic diseases is growing, but is based on observational data. Antibiotic use causes changes in the gut microbiome, and this may cause immune system changes that subsequently increase the risk of some conditions.[3-5,19] Antibiotic use in young children and babies is associated with an increased risk of asthma.[3,20,21] Childhood use of certain antibiotics is associated with an increased risk of weight gain, and the risk is higher with more courses of antibiotics.[6,22] Childhood antibiotic use is also associated with an increased risk of developing Crohn's disease.[4,23] The incidence of inflammatory bowel disease in children has increased markedly in Australia and worldwide, and antibiotic use has been suggested as a contributor to this trend.[24-27]

About the data

Data are sourced from the Pharmaceutical Benefits Scheme (PBS) dataset. This dataset includes all prescriptions dispensed under the PBS or the Repatriation Pharmaceutical Benefits Scheme, including prescriptions that do not receive an Australian Government subsidy. Note that some dispensed medicines may not be used.

The dataset does not include prescriptions dispensed for patients during their admission to public hospitals, discharge prescriptions dispensed from public hospitals in New South Wales and the Australian Capital Territory, direct supply of medicines to remote Aboriginal health services, over-the-counter purchase of medicines, doctor's bag medicines or private prescriptions.

Rates are based on the number of prescriptions dispensed for systemic antibiotics per 100,000 children aged 0–9 years in 2016–17. Antibiotics used orally, intravenously and intramuscularly are included; topical antibiotics are not included.

The term 'antibiotics' is used rather than 'antimicrobials' in this data item because other antimicrobials (antifungals, antivirals and antiparasitics) are not included. Note that the repeat analysis of antimicrobial medicines (in Chapter 5, page 239) includes a wider range of antimicrobials, not only antibiotics.

The analysis and maps are based on the residential address of the patient recorded in the PBS prescription claim and not the location of the prescriber or the dispensing pharmacy.

Rates are age and sex standardised to allow comparisons between populations with different age and sex structures.

This analysis was not undertaken by Aboriginal and Torres Strait Islander status because this information was not available for the PBS data at the time of publication.

What do the data show?

Magnitude of variation

In 2016–17, there were 3,053,315 PBS prescriptions dispensed for antibiotics in children, representing 96,721 prescriptions per 100,000 children aged 9 years and under (the Australian rate).

The number of PBS prescriptions dispensed for antibiotics across 328* local areas (Statistical Area Level 3 – SA3), ranged from 9,707 to 159,688 per 100,000 children aged 9 years and under. The rate was **16.5 times as high** in the area with the highest rate compared to the area with the lowest rate. The number of prescriptions dispensed varied across states and territories, from 69,015 per 100,000 children aged 9 years and under in the Northern Territory to 102,339 in Queensland (Figures 1.4–1.7).

After the highest and lowest 10% of results were excluded and 264 SA3s remained, the number of prescriptions dispensed per 100,000 children aged 9 years and under was 1.7 times as high in the area with the highest rate compared to the area with the lowest rate.

Analysis by remoteness and socioeconomic status

Rates of antibiotic dispensing in children aged 9 years and under were higher in major cities than in other areas. Rates were higher in areas with lower socioeconomic status in major cities and inner regional areas. However, there was no clear pattern according to socioeconomic status in other remoteness categories. Low rates of antibiotic dispensing in some remote, low-socioeconomic-status areas may be underestimates because dispensing through Aboriginal health services is not captured in the data (Figure 1.8).

* There are 340 SA3s. For this item, data were suppressed for 12 SA3s due to a small number of prescriptions dispensed and/or population in an area.

Antibiotics dispensing in children, 9 years and under

Analysis by age group

The rate of antibiotic dispensing was higher for children aged 4 years and under (113,906 prescriptions per 100,000 children) than for children aged 5–9 years (80,417 prescriptions per 100,000 children). This pattern was consistent across all states and territories (Figure 1.2).

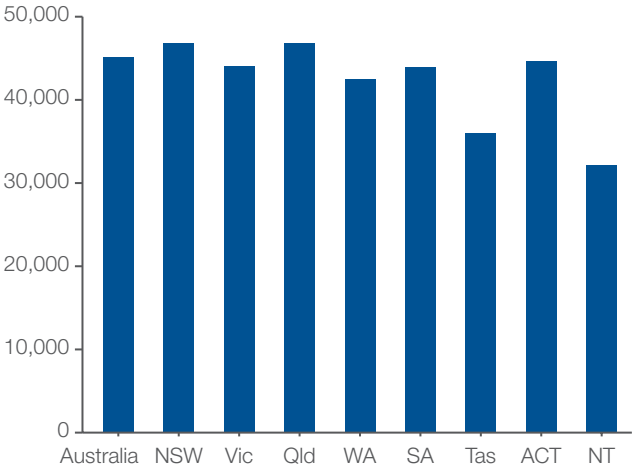
Figure 1.2: Number of PBS prescriptions dispensed for antibiotics per 100,000 children in specific age group, sex standardised, by state and territory of patient residence, 2016–17

The data for Figure 1.2 are available at www.safetyandquality.gov.au/atlas

Children dispensed at least one prescription

The number of children aged 9 years and under who had at least one prescription for an antibiotic dispensed in 2016–17 was 45,085 per 100,000 – that is, 45% of the child population aged 9 years and under. The rate varied from 32,108 per 100,000 children aged 9 years and under in the Northern Territory to 46,824 per 100,000 in New South Wales (Figure 1.3).

Figure 1.3: Number of children dispensed at least one antibiotic per 100,000 children aged 9 years and under, age and sex standardised, by state and territory of patient residence, 2016–17



The data for Figure 1.3 are available at www.safetyandquality.gov.au/atlas

Notes:
For further detail about the methods used, please refer to the Technical Supplement.
Source: AIHW analysis of Pharmaceutical Benefits Scheme data and ABS Estimated Resident Population 30 June 2016.

Interpretation

The overall rates of antibiotic dispensing in children aged 9 years and under are high. Variation in rates of antibiotic dispensing is likely to be due to geographical differences in the factors discussed below.

Clinical decision-making

Differences in clinicians' perceptions, attitudes towards managing patient illness and patient expectations, and prescribing behaviour will affect patterns of antibiotic prescribing.[28] Clinician adherence to guidelines about antibiotic use (for example, prescribing antibiotics for upper respiratory tract infections only when a bacterial infection is identified) is likely to affect rates of dispensing. Clinician non-adherence to guidelines, such as prescribing antibiotics for viral infections, will contribute to higher rates of inappropriate antibiotic use.

Socioeconomic status and health literacy

Parents with lower levels of education may have a poorer understanding of viral versus bacterial causes of childhood illnesses, and may have a greater expectation of antibiotic prescription for viral illnesses.[29,30] Other groups with low health literacy may also have higher expectations of antibiotic prescription, which in turn influences GP prescribing behaviour.[29-31] In some cases, prescribers may incorrectly assume that patients expect a prescription for an antibiotic.[31]

Rates of underlying illnesses

The local rate of bacterial infections that require antibiotic treatment is likely to affect rates of dispensing. Rates in some areas may be increased by small numbers of patients who require frequent antibiotics – for example, children with chronic diseases such as cystic fibrosis. Variation could also be influenced by local rates of influenza (flu) vaccination, as this could affect the number of patients seeking antibiotics during the flu season.

The burden of infectious disease tends to be higher in low-income communities.[32,33] The rate of infections may be influenced by social and housing conditions, including smoking in the household and overcrowding, and other factors such as climate.[34,35] Low rates of antibiotic dispensing in some remote, socioeconomically disadvantaged areas may be underestimates because dispensing through Aboriginal medical services is not captured in the data.

Access to medical care

Geographic access to medical care and the ability to pay out of pocket costs, are likely to affect the rates of people seeking care from clinicians for conditions that may require antibiotic treatment, or that are believed to require treatment, and subsequent rates of antibiotic dispensing. Clinicians treating patients who face financial or geographical barriers to accessing care may be more likely to prescribe opportunistically because of uncertain follow-up of the patient. Additionally, clinicians in regional and remote Australia may have less access to pathology services to support their decision-making.

Data limitations

Rates in remote geographic areas with high proportions of Aboriginal and Torres Strait Islander children are likely to be artificially low because the PBS dataset does not include data from Aboriginal health services, which supply medicines under the S100 scheme (an alternative arrangement for supplying PBS medicines).

Rates of prescriptions dispensed could be different from rates of medicines consumed.

Antibiotics dispensing in children, 9 years and under

Promoting appropriate care

Increasing antibiotic resistance highlights the urgency of reducing Australia's rate of inappropriate antibiotic use in children[1], especially in the areas shown to have the highest rates. Although the link between childhood antibiotic use and diseases in later life is not firmly established, this possibility adds to the case for restricting antibiotic use to situations where the need for antibiotics is clear.

Many groups have been working to reduce inappropriate antibiotic use in Australia; some success has been seen, but major challenges remain.[7-10] Antimicrobial use in Australian hospitals has been declining since the peak usage rate in 2010.[2] However, most antibiotic use occurs in the community.[2] The rate of antimicrobial prescribing in the community in Australia peaked in 2008, and the rate in 2015 was very similar, with more than 30 million prescriptions for antimicrobials in Australia in 2015.[2,11] Sustained efforts, combining different approaches, will be needed to make a difference to community prescribing.

A lack of access to data on dispensing from Aboriginal health services limited the current analysis, and initiatives to include these data are vital to providing a more complete picture of antibiotic use across Australia. Differences in the burden of disease need to be taken into account when interpreting antibiotic use in different settings. Interventions to address antibiotic resistance need to take into account differences in the type of infections in Aboriginal and Torres Strait Islander children in some areas compared with other children, as well as cultural differences.[36,37]

In an Australian survey of GPs, patient expectations were the main reason given for prescribing antibiotics for an upper respiratory tract infection.[31] This overarching reason may include other factors such as limited time, poor doctor–patient communication and diagnostic uncertainty.[31]

Communication skills training for prescribers and shared decision making have been successful in reducing antibiotic use for respiratory tract infections in the community.[38,39] Communication skills training evaluated in trials involved learning to deal with perceived pressure to prescribe, and to communicate with patients about their expectations on antibiotic prescribing.[38] This training reduced the rate of antibiotic prescribing for lower respiratory tract infections from 54% to 27% among patients in a Dutch trial.[40] A multi-centre European trial reported a reduction in primary care antibiotic prescribing for upper respiratory tract infections from 45% to 36% with internet-based communication skills training.[41]

Shared decision making has been shown to reduce the rate of antibiotic prescribing for acute respiratory infections in general practice from 47% to 29%.[12] In shared decision making interventions, the patient and clinician discuss the benefits and harms of antibiotic treatment, and the evidence of antibiotic effectiveness.[13] Patient decision aids on antimicrobial use, including for sore throat, acute bronchitis and middle ear infection in children, have been developed for use in the Australian primary care setting.[42-44] Interventions that promote shared decision making could also provide clinicians with skills that can be used in the management of other conditions, which may add to the cost-effectiveness of this approach.[39]

Counselling about appropriate use of antibiotics can be more time-consuming than writing a prescription, and time pressures on doctors are a contributor to inappropriate antibiotic prescribing.[31] Using resources to aid explanations of why an antibiotic prescription is not appropriate for some conditions, and support from nurse practitioners in counselling patients about antibiotic use, could help reduce inappropriate prescribing.

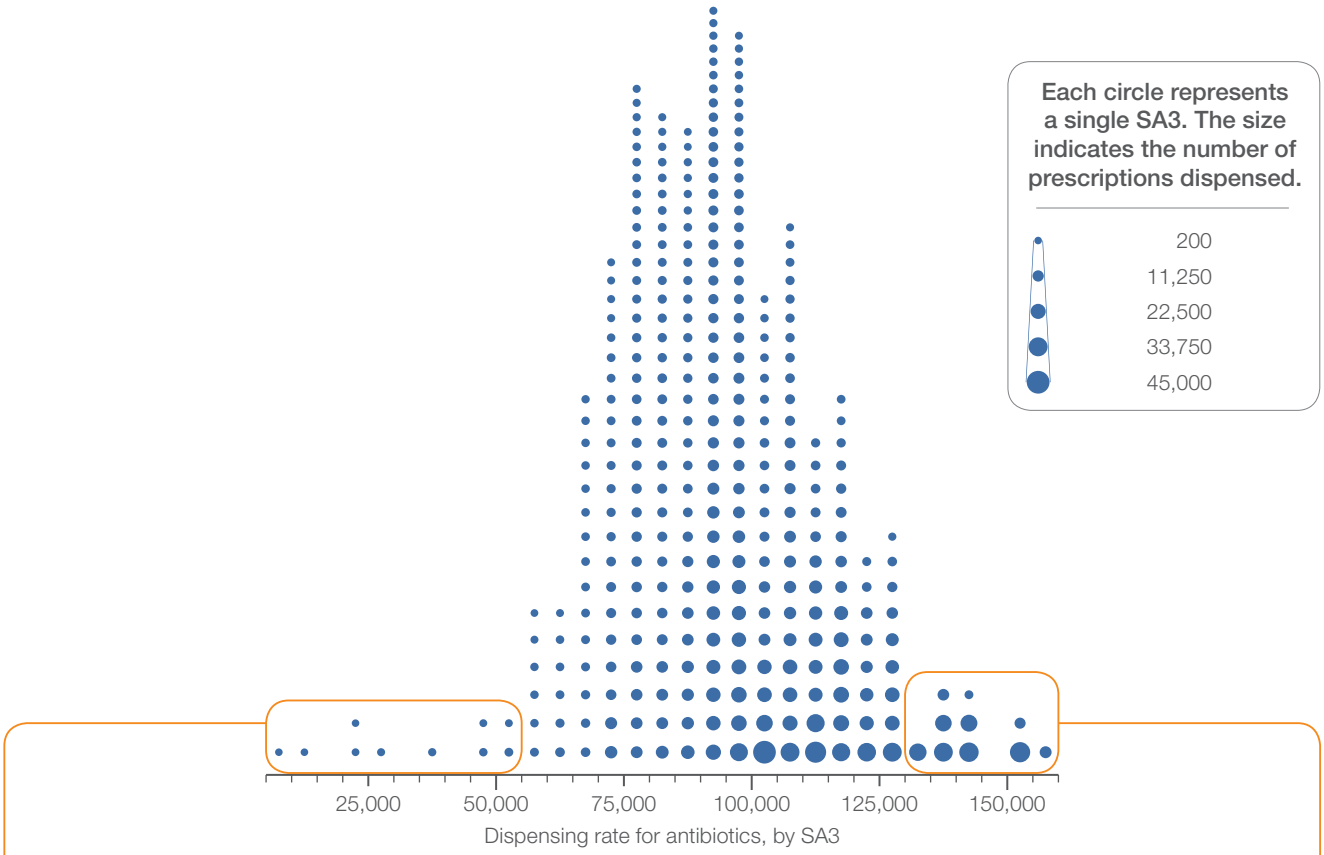
Public education is essential for supporting any interventions targeting prescribers, and ongoing, repeated efforts are required to make a substantial change in public awareness of the issues concerning antibiotic prescribing.[11,45] NPS MedicineWise has led programs to reduce the inappropriate use of antibiotics in Australia, including academic detailing and prescribing feedback for GPs, as well as public awareness campaigns.[11] Some success has been seen; for example, NPS MedicineWise campaigns between 2009 and 2015 were estimated to have resulted in a reduction of 14% in antibiotic dispensing volumes over this period.[46] However, data showing that GPs prescribe antibiotics at 4–9 times the rate expected if guidelines were followed highlight the size of the challenge that remains.[1]

A variety of other interventions could help reduce overuse of antibiotics in Australia – for example, changes to prescribing software so the default option for antibiotic prescriptions is 'no repeats', and aligning the dispensed amount of antibiotic with the recommended duration of therapy to avoid leftover doses.[11] Providing antibiotic prescriptions to patients with respiratory tract infections for use if symptoms do not resolve (delayed prescriptions) is another strategy that reduces unnecessary use of antibiotics.[47]

Antibiotics dispensing in children, 9 years and under

Rates by local area

Figure 1.4: Number of PBS prescriptions dispensed for antibiotics per 100,000 children aged 9 years and under, age and sex standardised, by Statistical Area Level 3 (SA3) of patient residence, 2016–17



Lowest rate areas

SA3	State	Rate	Prescriptions
Daly - Tiwi - West Arnhem	NT	**9,707**	316
East Arnhem	NT	**13,446**	375
Barkly	NT	**23,535**	271
Katherine	NT	**24,302**	915
Alice Springs	NT	**29,028**	1,741
Kimberley	WA	**35,930**	2,319
Far North	Qld	**48,065**	2,957
Huon - Bruny Island	Tas	**48,730**	1,103
Esperance	WA	**50,215**	1,125
Augusta - Margaret River - Busselton	WA	**54,387**	4,029

Highest rate areas

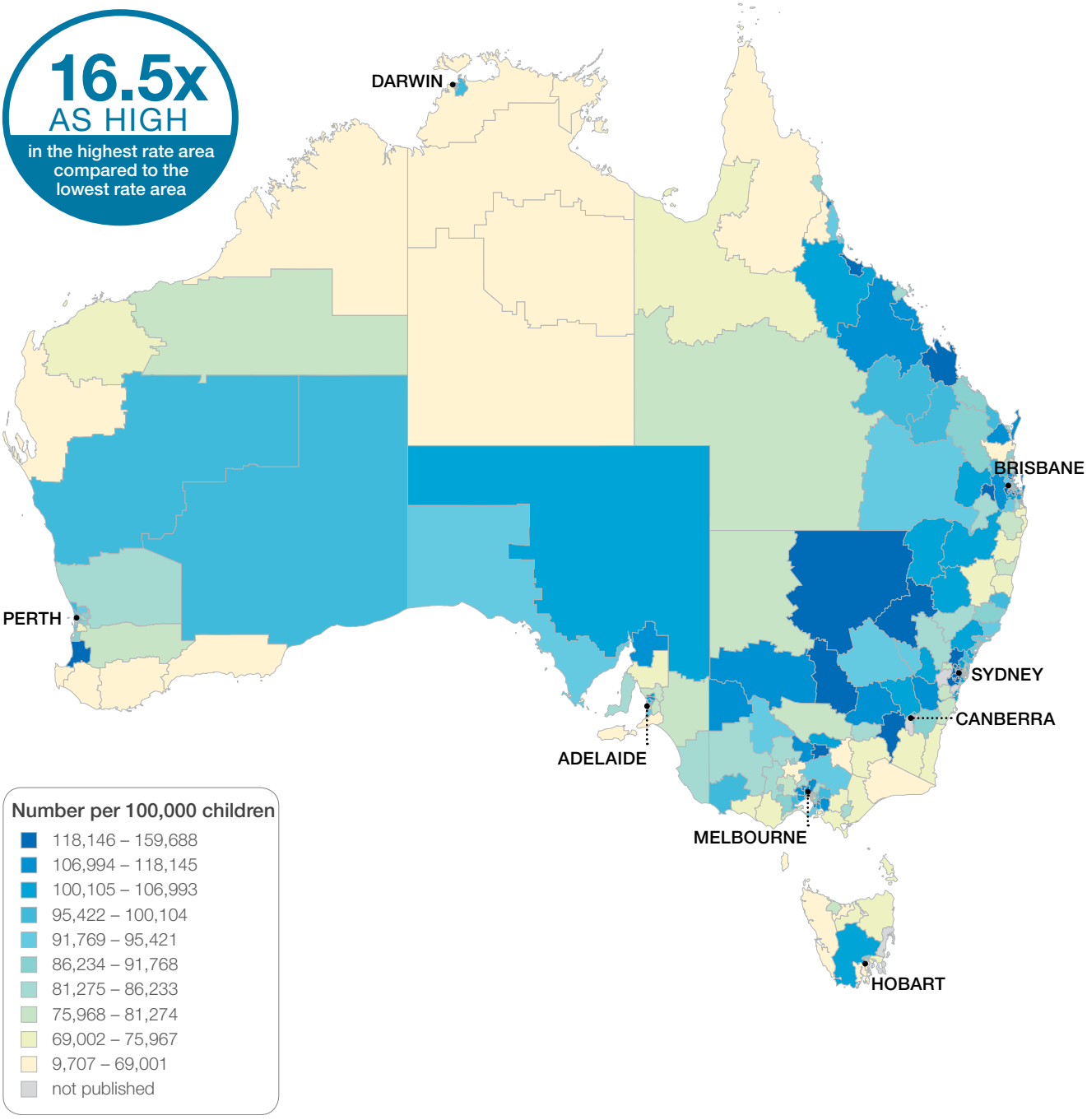
SA3	State	Rate	Prescriptions
St Marys	NSW	**159,688**	13,152
Fairfield	NSW	**154,713**	37,602
Griffith - Murrumbidgee (West)	NSW	**152,566**	10,681
Campbelltown (NSW)	NSW	**142,501**	35,189
Bribie - Beachmere	Qld	**142,207**	4,113
Mount Druitt	NSW	**141,411**	27,748
Liverpool	NSW	**137,887**	26,855
Shepparton	Vic	**136,694**	12,329
Merrylands - Guildford	NSW	**136,160**	33,383
Penrith	NSW	**132,552**	29,335

Notes:
For further detail about the methods used, please refer to the Technical Supplement.
Sources: AIHW analysis of Pharmaceutical Benefits Scheme data and ABS Estimated Resident Population 30 June 2016.

Antibiotics dispensing in children, 9 years and under

Rates across Australia

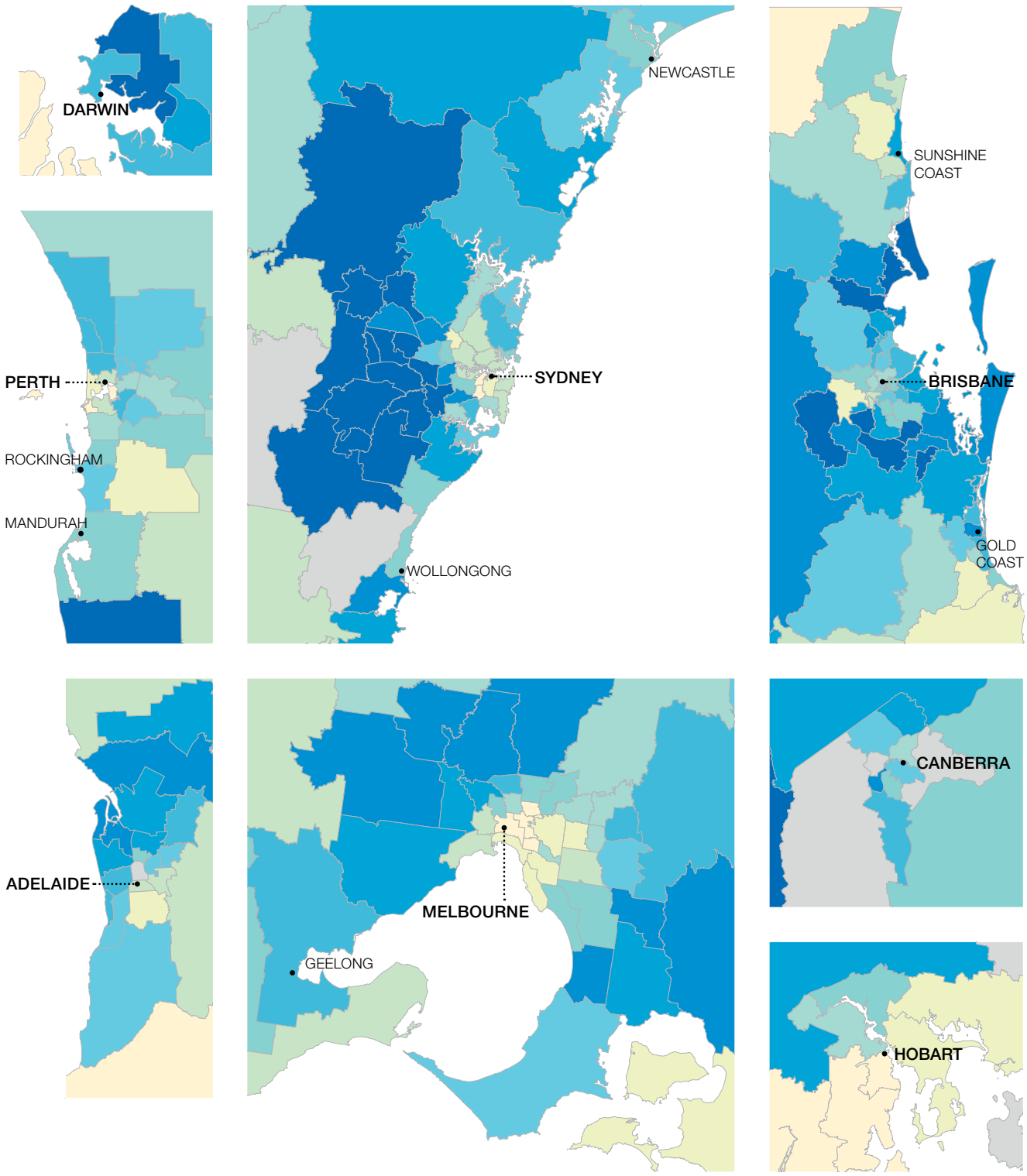
Figure 1.5: Number of PBS prescriptions dispensed for antibiotics per 100,000 children aged 9 years and under, age and sex standardised, by Statistical Area Level 3 (SA3) of patient residence, 2016–17



Notes:
For further detail about the methods used, please refer to the Technical Supplement.
Sources: AIHW analysis of Pharmaceutical Benefits Scheme data and ABS Estimated Resident Population 30 June 2016.

Rates across capital city areas

Figure 1.6: Number of PBS prescriptions dispensed for antibiotics per 100,000 children aged 9 years and under, age and sex standardised, by Statistical Area Level 3 (SA3) of patient residence, 2016–17



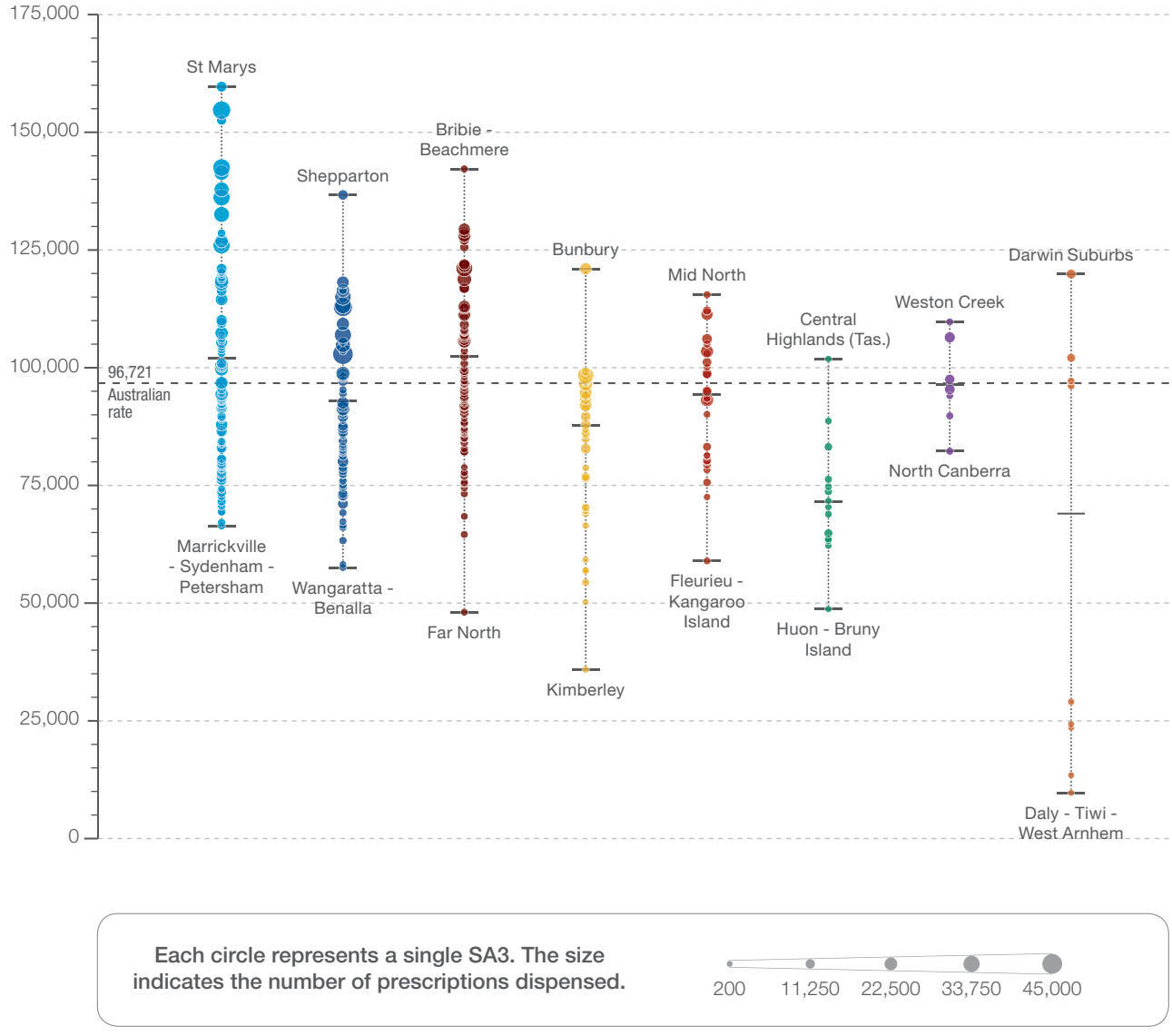
Notes:
For further detail about the methods used, please refer to the Technical Supplement.
Sources: AIHW analysis of Pharmaceutical Benefits Scheme data and ABS Estimated Resident Population 30 June 2016.

Antibiotics dispensing in children, 9 years and under

Rates by state and territory

Figure 1.7: Number of PBS prescriptions dispensed for antibiotics per 100,000 children aged 9 years and under, age and sex standardised, by Statistical Area Level 3 (SA3) of patient residence, 2016–17

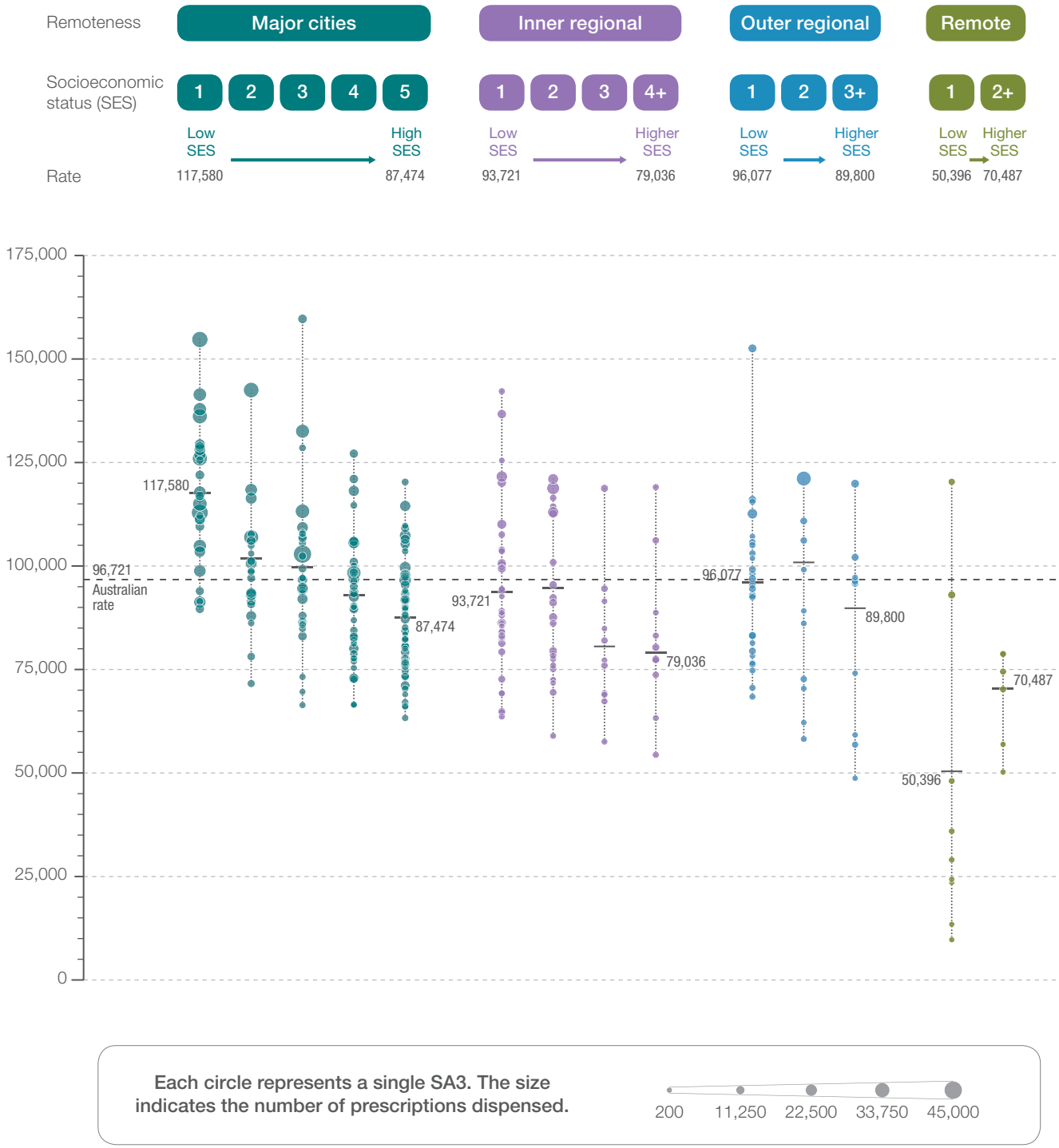
	NSW	Vic	Qld	WA	SA	Tas	ACT	NT
Highest rate	159,688	136,694	142,207	121,012	115,504	101,857	109,733	119,885
State/territory	101,950	93,018	102,339	87,662	94,312	71,472	96,447	69,015
Lowest rate	66,391	57,562	48,065	35,930	58,958	48,730	82,273	9,707
No. prescriptions	1,023,567	738,699	664,062	302,588	196,083	44,699	52,890	26,240



Notes:
For further detail about the methods used, please refer to the Technical Supplement.
Sources: AIHW analysis of Pharmaceutical Benefits Scheme data and ABS Estimated Resident Population 30 June 2016.

Rates by remoteness and socioeconomic status

Figure 1.8: Number of PBS prescriptions dispensed for antibiotics per 100,000 children aged 9 years and under, age and sex standardised, by Statistical Area Level 3 (SA3) of patient residence, 2016–17



Notes:
For further detail about the methods used, please refer to the Technical Supplement.
Sources: AIHW analysis of Pharmaceutical Benefits Scheme data and ABS Estimated Resident Population 30 June 2016.

Antibiotics dispensing in children, 9 years and under

Resources

- *Therapeutic Guidelines: Antibiotic*[48], including mobile app
- Australian Commission on Safety and Quality in Health Care, Antimicrobial Stewardship Clinical Care Standard[49]
- Australian Commission on Safety and Quality in Health Care, patient decision aids on antibiotic use for sore throat, acute bronchitis and middle ear infection[42-44]
- Australian Commission on Safety and Quality in Health Care, *Helping Patients Make Informed Decisions: Communicating risks and benefits* (eLearning module)[50]
- NPS MedicineWise, *What Every Parent Should Know About Colds, Coughs, Earaches and Sore Throats*
- NPS MedicineWise, antimicrobial learning modules
- Australian Government, Nurses and antimicrobial resistance fact sheet
- Australian Government, What health professionals can do; What you can do (infographics)
- National Centre for Antimicrobial Stewardship, 'Antimicrobial prescribing in children' (infographic).[51]

Australian initiatives

The information in this chapter will complement work already under way to improve the appropriateness of antibiotic use in children in Australia. At a national level, this work includes:

- Antimicrobial Stewardship Clinical Care Standard and accompanying indicators[49]
- Antibiotic Awareness Week
- Antimicrobial Use and Resistance in Australia (AURA) Surveillance System[2]
- *Australia's First National Antimicrobial Resistance Strategy 2015–2019*[10]
- National Antimicrobial Prescribing Survey, education and training[10]
- National Antimicrobial Utilisation Surveillance Program[52]
- NPS MedicineWise consumer and clinician interventions
- Royal Australian College of Physicians Paediatrics Child Health Division, Choosing Wisely recommendation 1: Do not routinely prescribe oral antibiotics to children with fever without an identified bacterial infection[53]
- Royal Australian College of General Practitioners, Choosing Wisely recommendation 9: Don't treat otitis media (middle ear infection) with antibiotics, in non-Indigenous children aged 2–12 years, where reassessment is a reasonable option[9]
- Australian Society of Infectious Diseases, Choosing Wisely recommendations 1–4:
  - Do not use antibiotics for asymptomatic bacteriuria
  - Do not take a swab or use antibiotics for the management of a leg ulcer without clinical infection
  - Avoid prescribing antibiotics for upper respiratory tract infection
  - Do not investigate or treat for faecal pathogens in the absence of diarrhoea or other gastrointestinal symptoms.[54]

Many state and territory initiatives are also in place to improve the appropriateness of antibiotic use in children, including antimicrobial stewardship programs and guidelines for managing childhood infections. For example:

- The Tasmanian Infection Prevention and Control Unit provides feedback to rural inpatient facilities and GP prescribers on their antimicrobial prescribing, and Primary Health Tasmania provides education on antimicrobial prescribing
- Safer Care Victoria, New South Wales Health and Queensland Health have recently developed the Paediatric Improvement Collaborative; this involves a tri-state memorandum of understanding and funding agreement to enable New South Wales Health and Queensland Health to formally use the Victorian clinical practice guidelines.

Antibiotics dispensing in children, 9 years and under

References

1. McCullough AR, Pollack AJ, Plejdrup Hansen M, Glasziou PP, Looke DF, Britt HC, et al. Antibiotics for acute respiratory infections in general practice: comparison of prescribing rates with guideline recommendations. Med J Aust 2017;207(2):65–9.
2. Australian Commission on Safety and Quality in Health Care. AURA 2017: second Australian report on antimicrobial use and resistance in human health. Sydney: ACSQHC; 2017.
3. Ahmadizar F, Vijverberg SJ, Arets HG, de Boer A, Turner S, Devereux G, et al. Early life antibiotic use and the risk of asthma and asthma exacerbations in children. Pediatr Allergy Immunol 2017;28(5):430–7.
4. Ungaro R, Bernstein CN, Gearry R, Hviid A, Kolho KL, Kronman MP, et al. Antibiotics associated with increased risk of new-onset Crohn's disease but not ulcerative colitis: a meta-analysis. Am J Gastroenterol 2014;109(11):1728–38.
5. Korpela K, Salonen A, Virta LJ, Kekkonen RA, Forslund K, Bork P, et al. Intestinal microbiome is related to lifetime antibiotic use in Finnish pre-school children. Nat Commun 2016;7:10410.
6. Rasmussen SH, Shrestha S, Bjerregaard LG, Angquist LH, Baker JL, Jess T, et al. Antibiotic exposure in early life and childhood overweight and obesity: a systematic review and meta-analysis. Diabetes Obes Metab 2018;20(6):1508–14.
7. Australasian Society for Infectious Diseases. Five things clinicians and consumers should question. Sydney: NPS MedicineWise; 2016.
8. Organisation for Economic Co-operation and Development. Health at a glance 2017: OECD indicators. Figure 6.5. Paris: OECD Publishing; 2017.
9. Choosing Wisely Australia. Royal Australian College of General Practitioners: tests, treatments and procedures clinicians and consumers should question – recommendation 9 [Internet]. Sydney: NPS MedicineWise; 2016 [updated 2016 Mar; cited 2018 Jul 20]. Available from: www.choosingwisely.org.au/recommendations/racgp
10. Department of Health, Department of Agriculture and Water Resources. Australia's first national antimicrobial resistance strategy 2015–2019: progress report. Canberra: Australian Government; 2017.
11. Del Mar CB, Scott AM, Glasziou PP, Hoffmann T, van Driel ML, Beller E, et al. Reducing antibiotic prescribing in Australian general practice: time for a national strategy. Med J Aust 2017;207(9):401–6.
12. Coxeter P, Del Mar CB, McGregor L, Beller EM, Hoffmann TC. Interventions to facilitate shared decision making to address antibiotic use for acute respiratory infections in primary care. Cochrane Database Syst Rev 2015;(11):CD010907.
13. Hoffmann TC, Del Mar CB. Shared decision making: what do clinicians need to know and why should they bother? Med J Aust 2014;201(9):513–14.
14. Drug Utilisation Sub-Committee. Antibiotics: PBS/RPBS utilisation. Pharmaceutical Benefits Scheme (PBS), October 2014 and February 2015 [Internet]. Canberra: Australian Government Department of Health [updated 2015 May 29; cited 2018 Jul 20]. Available from: www.pbs.gov.au/info/industry/listing/participants/public-release-docs/antibiotics/antibiotics-oct-14-feb-15
15. Biezen R, Pollack AJ, Harrison C, Brijnath B, Grando D, Britt HC, et al. Respiratory tract infections among children younger than 5 years: current management in Australian general practice. Med J Aust 2015;202(5):262–6.
16. NPS MedicineWise. Antibiotic resistance in Australia: here and now [Internet]. Sydney: NPS MedicineWise; 2016 [updated 2016 Nov 11; cited 2018 Jul 20]. Available from: www.nps.org.au/news/antibiotic-resistance-in-australia-here-and-now#current-trends-in-resistance
17. Costelloe C, Metcalfe C, Lovering A, Mant D, Hay AD. Effect of antibiotic prescribing in primary care on antimicrobial resistance in individual patients: systematic review and meta-analysis. BMJ 2010;340:c2096.
18. Bryce A, Costelloe C, Hawcroft C, Wootton M, Hay AD. Faecal carriage of antibiotic resistant *Escherichia coli* in asymptomatic children and associations with primary care antibiotic prescribing: a systematic review and meta-analysis. BMC Infect Dis 2016;16:359.
19. Doan T, Arzika AM, Ray KJ, Cotter SY, Kim J, Maliki R, et al. Gut microbial diversity in antibiotic-naive children after systemic antibiotic exposure: a randomized controlled trial. Clin Infect Dis 2017;64(9):1147–53.
20. Mitre E, Susi A, Kropp LE, Schwartz DJ, Gorman GH, Nylund CM. Association between use of acid-suppressive medications and antibiotics during infancy and allergic diseases in early childhood. JAMA Pediatr 2018;172(6):e180315.
21. Penders J, Kummeling I, Thijs C. Infant antibiotic use and wheeze and asthma risk: a systematic review and meta-analysis. Eur Respir J 2011;38(2):295–302.
22. Shao X, Ding X, Wang B, Li L, An X, Yao Q, et al. Antibiotic exposure in early life increases risk of childhood obesity: a systematic review and meta-analysis. Front Endocrinol (Lausanne) 2017;8:170.
23. Theochari NA, Stefanopoulos A, Mylonas KS, Economopoulos KP. Antibiotics exposure and risk of inflammatory bowel disease: a systematic review. Scand J Gastroenterol 2018;53(1):1–7.
24. Schildkraut V, Alex G, Cameron DJ, Hardikar W, Lipschitz B, Oliver MR, et al. Sixty-year study of incidence of childhood ulcerative colitis finds eleven-fold increase beginning in 1990s. Inflamm Bowel Dis 2013;19(1):1–6.
25. Phavichitr N, Cameron DJ, Catto-Smith AG. Increasing incidence of Crohn's disease in Victorian children. J Gastroenterol Hepatol 2003;18(3):329–32.
26. Benchimol EI, Fortinsky KJ, Gozdyra P, Van den Heuvel M, Van Limbergen J, Griffiths AM. Epidemiology of pediatric inflammatory bowel disease: a systematic review of international trends. Inflamm Bowel Dis 2011;17(1):423–39.
27. Shouval DS, Rufo PA. The role of environmental factors in the pathogenesis of inflammatory bowel diseases: a review. JAMA Pediatr 2017;171(10):999–1005.
28. Patel SV, Vergnano S. The impact of paediatric antimicrobial stewardship programmes on patient outcomes. Curr Opin Infect Dis 2018;31(3):216–23.
29. Vaz LE, Kleinman KP, Lakoma MD, Dutta-Linn MM, Nahill C, Hellinger J, et al. Prevalence of parental misconceptions about antibiotic use. Pediatrics 2015;136(2):221–31.
30. Gaarslev C, Yee M, Chan G, Fletcher-Lartey S, Khan R. A mixed methods study to understand patient expectations for antibiotics for an upper respiratory tract infection. Antimicrob Resist Infect Control 2016;5:39.
31. Fletcher-Lartey S, Yee M, Gaarslev C, Khan R. Why do general practitioners prescribe antibiotics for upper respiratory tract infections to meet patient expectations: a mixed methods study. BMJ Open 2016;6(10):e012244.
32. Laxminarayan R, Matsoso P, Pant S, Brower C, Rottingen JA, Klugman K, et al. Access to effective antimicrobials: a worldwide challenge. Lancet 2016;387(10014):168–75.
33. Chang AB, Grimwood K, Maguire G, King PT, Morris PS, Torzillo PJ. Management of bronchiectasis and chronic suppurative lung disease in Indigenous children and adults from rural and remote Australian communities. Med J Aust 2008;189(7):386–93.
34. Quinn EK, Massey PD, Speare R. Communicable diseases in rural and remote Australia: the need for improved understanding and action. Rural Remote Health 2015;15(3):3371.
35. Jones LL, Hashim A, McKeever T, Cook DG, Britton J, Leonardi-Bee J. Parental and household smoking and the increased risk of bronchitis, bronchiolitis and other lower respiratory infections in infancy: systematic review and meta-analysis. Respir Res 2011;12:5.
36. Oliver SJ, Cush J, Ward JE. Community-based prescribing for impetigo in remote Australia: an opportunity for antimicrobial stewardship. Front Public Health 2017;5:158.
37. Dunne EM, Carville K, Riley TV, Bowman J, Leach AJ, Cripps AW, et al. Aboriginal and non-Aboriginal children in Western Australia carry different serotypes of pneumococci with different antimicrobial susceptibility profiles. Pneumonia (Nathan) 2016;8:15.
38. Kochling A, Loffler C, Reinsch S, Hornung A, Bohmer F, Altiner A, et al. Reduction of antibiotic prescriptions for acute respiratory tract infections in primary care: a systematic review. Implement Sci 2018;13(1):47.
39. Tonkin-Crine SK, Tan PS, van Hecke O, Wang K, Roberts NW, McCullough A, et al. Clinician-targeted interventions to influence antibiotic prescribing behaviour for acute respiratory infections in primary care: an overview of systematic reviews. Cochrane Database Syst Rev 2017;(9):CD012252.
40. Cals JW, Butler CC, Hopstaken RM, Hood K, Dinant GJ. Effect of point of care testing for C reactive protein and training in communication skills on antibiotic use in lower respiratory tract infections: cluster randomised trial. BMJ 2009;338:b1374.

41. Little P, Stuart B, Francis N, Douglas E, Tonkin-Crine S, Anthierens S, et al. Effects of internet-based training on antibiotic prescribing rates for acute respiratory-tract infections: a multinational, cluster, randomised, factorial, controlled trial. Lancet 2013;382(9899):1175–82.
42. Hoffman T, Del Mar C, Coxeter P. Acute bronchitis: should I take antibiotics? Sydney: ACSQHC; 2016.
43. Hoffman T, Del Mar C, Coxeter P. Middle ear infection: should my child take antibiotics? Sydney: ACSQHC; 2016.
44. Hoffman T, Del Mar C, Coxeter P. Sore throat: should I take antibiotics? Sydney: ACSQHC; 2016.
45. Sabuncu E, David J, Bernede-Bauduin C, Pepin S, Leroy M, Boelle PY, et al. Significant reduction of antibiotic use in the community after a nationwide campaign in France, 2002–2007. PLoS Med 2009;6(6):e1000084.
46. Wu J, Taylor D, Ovchinikova L, Heaney A, Morgan T, Dartnell J, et al. Relationship between antimicrobial-resistance programs and antibiotic dispensing for upper respiratory tract infection: an analysis of Australian data between 2004 and 2015. J Int Med Res 2018;46(4):1326–38.
47. Spurling GK, Del Mar CB, Dooley L, Foxlee R, Farley R. Delayed antibiotic prescriptions for respiratory infections. Cochrane Database Syst Rev 2017;(9):CD004417.
48. Therapeutic guidelines: antibiotic. Version 15 [Internet]. Melbourne: Therapeutic Guidelines Limited; 2014 [cited 2018 Jul 20]. Available from: www.tg.org.au
49. Australian Commission on Safety and Quality in Health Care. Antimicrobial stewardship clinical care standard. Sydney: ACSQHC; 2014.
50. Australian Commission on Safety and Quality in Health Care. Helping patients make informed decisions: communicating risks and benefits (eLearning module) [Internet]. Sydney: ACSQHC; 2017 [cited 2018 Jul 20]. Available from: https://contenttest.learningseat.com/safetyandquality/index.html
51. National Centre for Antimicrobial Stewardship. Antimicrobial prescribing in children infographic. Melbourne: NCAS [cited 2018 Jul 20]. Available from: irp-cdn.multiscreensite.com/d820f98f/files/uploaded/10.%20Paeds%20Final.pdf.
52. SA Health, Australian Commission on Safety and Quality in Health Care. Antimicrobial use in Australian hospitals: 2016 annual report of the National Antimicrobial Utilisation Surveillance Program. Sydney: ACSQHC; 2018.
53. Choosing Wisely Australia. RACP Paediatrics and Child Health Division: tests, treatments and procedures clinicians and consumers should question – recommendation 1 [Internet]. Sydney: NPS MedicineWise; 2017 [updated 2017 Sep 25; cited 2018 Jul 20]. Available from: www.choosingwisely.org.au/recommendations/paediatrics-and-child-health-division-(racp)
54. Choosing Wisely Australia. Australasian Society for Infectious Diseases: tests, treatments and procedures clinicians and consumers should question – recommendations 1–4 [Internet]. Sydney: NPS MedicineWise; 2016 [updated 2016 Mar 1; cited 2018 Jul 20]. Available from: www.choosingwisely.org.au/recommendations/asid